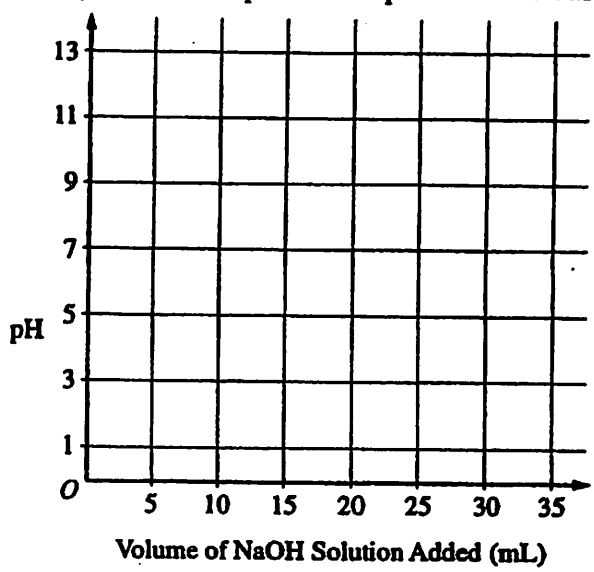
LABORATORY

1. An approximately 0.1-molar solution of NaOH is to be standardized by titration. Assume that the following materials are available.
   - Clean, dry 50 mL buret
   - 250 mL Erlenmeyer flask
   - Wash bottle filled with distilled water
   - Analytical balance
   - Phenolphthalein indicator solution
   - Potassium hydrogen phthalate, KHP, a pure solid monoprotic acid (to be used as the primary standard)

(a) Briefly describe the steps you would take, using the materials listed above, to standardize the NaOH solution.

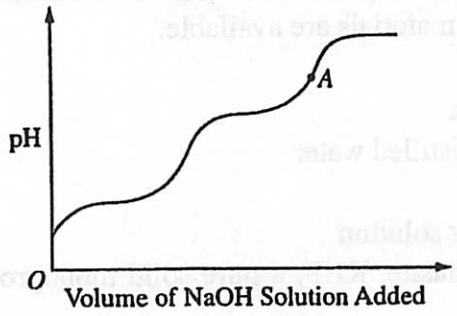
(b) Describe (*i.e.*, set up) the calculations necessary to determine the concentration of the NaOH solution.

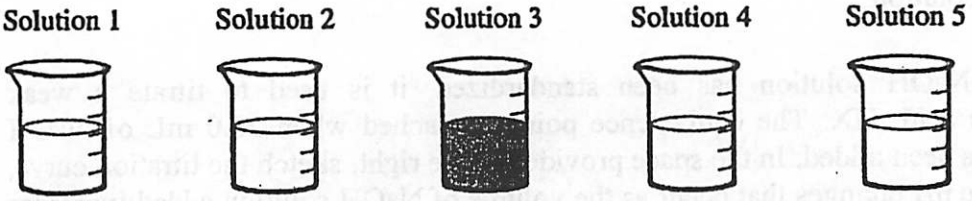
(c) After the NaOH solution has been standardized, it is used to titrate a weak monoprotic acid, HX. The equivalence point is reached when 25.0 mL of NaOH solution has been added. In the space provided at the right, sketch the titration curve, showing the pH changes that occur as the volume of NaOH solution added increases from 0 to 35.0 mL. Clearly label the equivalence point on the curve.



(d) Describe how the value of the acid-dissociation constant, K_a, for the weak acid HX could be determined from the titration curve in part (c).

(e) The graph below shows the results obtained by titrating a different weak acid, H_2Y, with the standardized NaOH solution. Identify the negative ion that is present in the highest concentration at the point in the titration represented by the letter *A* on the curve.





2. Answer the questions below that relate to the five aqueous solutions at 25°C shown above.

(a) Which solution has the highest boiling point? Explain.
(b) Which solution has the highest pH? Explain.
(c) Identify a pair of the solutions that would produce a precipitate when mixed together. Write the formula of the precipitate.
(d) Which solution could be used to oxidize the $Cl^-(aq)$ ion? Identify the product of the oxidation.
(e) Which solution would be the least effective conductor of electricity? Explain.

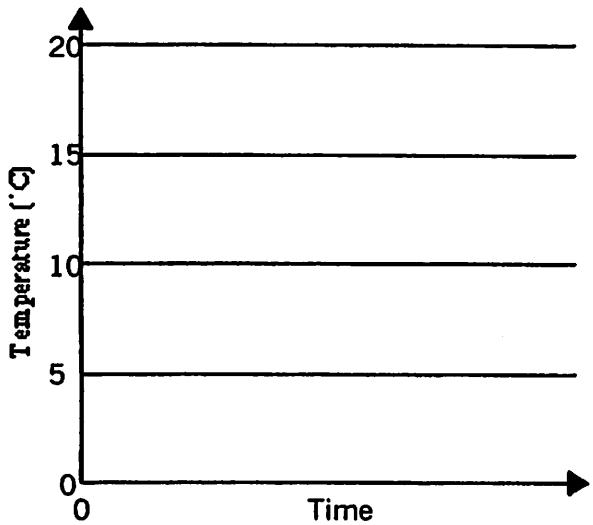
3.

The molar mass of an unknown solid, which is nonvolatile and a nonelectrolyte, is to be determined by the freezing-point depression method. The pure solvent used in the experiment freezes at 10°C and has a known molal freezing-point depression constant, K_f. Assume that the following materials are also available.

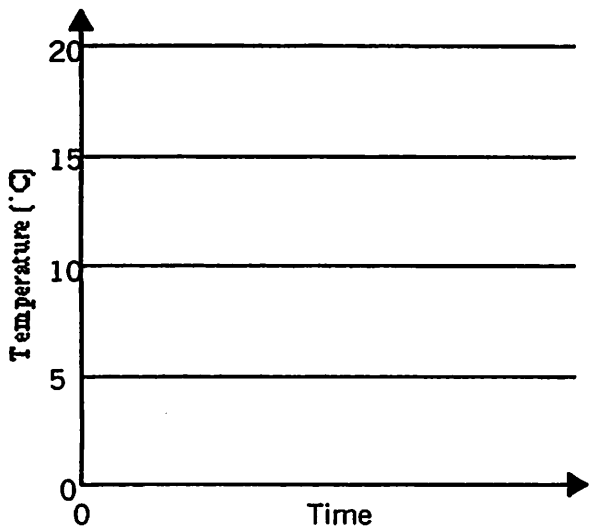
- test tubes
- stirrer
- pipet
- stopwatch
- graph paper
- thermometer
- balance
- beaker
- ice
- hot-water bath

(a) Using the two sets of axes provided below, sketch cooling curves for (i) the pure solvent and for (ii) the solution as each is cooled from 20°C to 0.0°C

Pure Solvent



Solution



(b) Information from these graphs may be used to determine the molar mass of the unknown solid.

(i) Describe the measurements that must be made to determine the molar mass of the unknown solid by this method.

(ii) Show the setup(s) for the calculation(s) that must be performed to determine the molar mass of the unknown solid from the experimental data.

(iii) Explain how the difference(s) between the two graphs in part (a) can be used to obtain information needed to calculate the molar mass of the unknown solid.

(c) Suppose that during the experiment a significant but unknown amount of solvent evaporates from the test tube. What effect would this have on (he calculated value of the molar mass of the solid (*i.e.*, too large, too small, or no effect)? Justify your answer.

(d) Show the setup for the calculation of the percentage error in a student's result if the student obtains a value of 126 g mol^{-1} for the molar mass of the solid when the actual value is 120. g mol^{-1}.

$$H^+(aq) + OH^-(aq) \quad H_2O(l)$$

4. A student is asked to determine the molar enthalpy of neutralization, ΔH_{neut}, for the reaction represented above. The student combines equal volumes of 1.0 *M* HC1 and 1.0 *M* NaOH in an open polystyrene cup calorimeter. The heat released by the reaction is determined by using the equation $q = mc\Delta T$.

Assume the following:

- Both solutions are at the same temperature before they are combined.
- The densities of all the solutions are the same as that of water.
- Any heat lost to the calorimeter or to the air is negligible.
- The specific heat capacity of the combined solutions is the same as that of water.

(a) Give appropriate units for each of the terms in the equation $q = mc\Delta T$.

(b) List the measurements that must be made in order to obtain the value of q.

(c) Explain how to calculate each of the following.

(i) The number of moles of water formed during the experiment

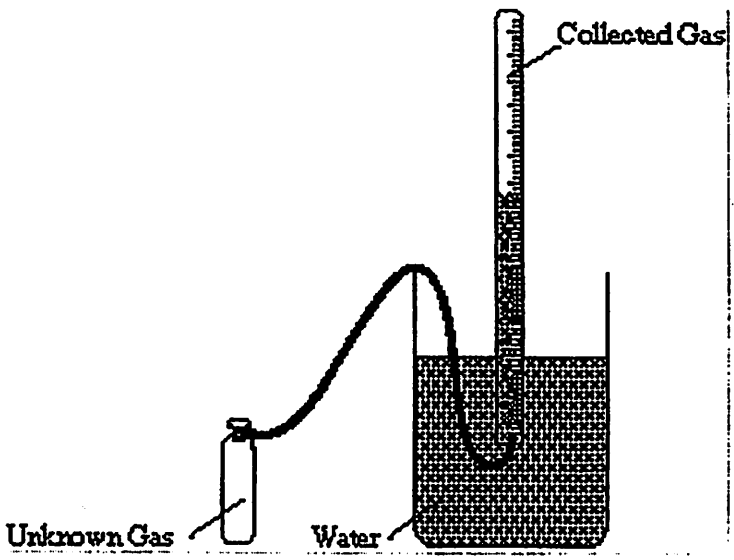
(ii) The value of the molar enthalpy of neutralization, ΔH_{neut}, for the reaction between HC1(*aq*) and NaOH(*aq*)

(d) The student repeats the experience with the same equal volumes as before, but this time uses 2.0 *M* HC1 and 2.0 *M* NaOH.

(a) Indicate whether the value of q increases, decreases, or stays the same when compared to the first experiment. Justify your prediction.

(b) Indicate whether the value of the molar enthalpy of neutralization, ΔH_{neut}, increases, decreases, or stays the same when compared to the first experiment. Justify your prediction.

(e) Suppose that a significant amount of heat were lost to the air during the experiment. What effect would this have on the calculated value of the molar enthalpy of neutralization, ΔH_{neut}? Justify your answer.



5. A student performs an experiment to determine the molar mass of an unknown gas. A small amount of the pure gas is released from a pressurized container and collected in a graduated tube over water at room temperature, as shown in the diagram above. The collection tube containing the gas is allowed to stand for several minutes, and its depth is adjusted until the water levels inside and outside the tube are the same. Assume that:
   - the gas is not appreciably soluble in water
   - the gas collected in the graduated tube and the water are in thermal equilibrium
   - a barometer, a thermometer, an analytical balance, and a table of the equilibrium vapor pressure of water at various temperatures are also available.

   (a) Write the equation(s) needed to calculate the molar mass of the gas.

   (b) List the measurements that must be made in order to calculate the molar mass of the gas.

   (c) Explain the purpose of equalizing the water levels inside and outside the gas collection tube.

   (d) The student determines the molar mass of the gas to be 64 g mol^{-1}. Write the expression (set-up) for calculating the percent error in the experimental value, assuming that the unknown gas is butane (molar mass 58 g mol^{-1}). Calculations are not required.

   (e) If the student fails to use information from the table of the equilibrium vapor pressures of water in the calculation, the calculated value for the molar mass of the unknown gas will be smaller than the actual value. Explain.